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HYPOTENSION
Shock and Cardiocirculatory Failure

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INTRODUCTION

A sudden fall in blood pressure is a common occurrence in many conditions It is a symptom found at the bedside in the operating room and in the emergency ward Whether due to blood loss cardiac arrhythmia or vasomotor paralysis it must be dealt with promptly to prevent the changes that may lead to death from severe or prolonged hypotension Treatment to be effective must be based on an understanding of the mechanisms involved in the development of hypotension Recognition of its causes and a knowledge of the methods and the drugs available for the restoration of normal blood pressure are of equal importance in therapy

Shock is no longer an enigma The cause and the treatment of traumatic or surgical shock are now well known and as a consequence its morbidity and mortality have been reduced greatly However the subject is so important that even the well established facts about shock need re emphasis and repetition Furthermore the experience of the past few years has added new knowledge

Hypotension during surgical operation is a common occurrence Further improvement in preoperative and postoperative care depends on an understanding of the factors other than blood loss that may be responsible for a fall in blood pressure The effects of anesthetic medication and procedures of operation itself especially in the elderly and those with cardiovascular disease the use of blood fractions and substitutes norepinephrine and other drugs are some of

the more recent advances that require consideration

Many new facts about hypotension from laboratory and clinical studies have accumulated in recent years Some of them are to be found in monographs on shock others in textbooks and journals of cardiology medicine surgery and anesthesia Therefore it was considered worth while to bring together in a single volume as many of these facts as would be helpful in the clinical management of any patient who suddenly develops low blood pressure. Its incidence and urgency especially among the increasing number of older patients undergoing major surgery are further reasons for presenting the established facts about the problem so that the causes of hypotension may be better known and its treatment improved

Most of the material presented herein has been derived from experiences in the clinical investigation and treatment of peripheral circulatory failure at the Royal Victoria Hospital over the past 15 years These have formed the basis but the experiences of others also have been drawn upon They are too numerous to mention but the bibliography contains the most recent and complete review articles The combined experience of many who have investigated and treated shock and cardiocirculatory failure presented in a concise form in its practical aspects for clinicians has been the aim of the author in this treatise

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REGULATION OF THE NORMAL BLOOD PRESSURE

Blood pressure is regulated by a combination of factors having to do with the maintenance of the diastolic pressure and the production of systolic pressure The latter is primarily dependent on the amount of blood ejected by the left ventricle with each systole The resistance of the aorta to the blood entering it also plays a part The diastolic pressure is maintained by the resistance of the peripheral vascular system and to a lesser extent by the heart rate

The stroke volume or cardiac output per ventricular systole depends on the amount of blood that flows into the left ventricle from the lesser circulation The amount of blood that enters the pulmonary circuit in turn depends on the venous return to the right auricle The factors on which this depends are the blood volume and the peripheral blood flow

The resistance of the aorta to the blood flow during systole is determined by the size and the elasticity of the aorta This central resistance as it is called is increased by rigidity of the aortic walls A decrease in the capacity of the aorta also increases central resistance

Peripheral resistance is directly related to the caliber of the capillaries the venules and most impor

tant the arterioles It is regulated by three mechanisms (1) nervous impulses (2) hormonal agents and (3) the inherent tone of arteriolar smooth muscle An increase in intravascular pressure sets up impulses mediated through the autonomic pathways arising in the aortic arch and the carotid sinus which reach the vasomotor and cardiac centers in the medulla Efferent impulses originating in these centers slow the heart rate and decrease arteriolar resistance thereby lowering both systolic and diastolic blood pressure The humoral agents that affect blood pressure are principally those of the adrenal gland cortical as well as medullary and the posterior pituitary Arteriolar tone is probably an inherent property of the vascular musculature which is only modulated by neural and humoral mechanisms

Because diastolic pressure falls as the duration of diastole is lengthened it is also dependent on heart rate The rate of the heart is regulated by the same nervous and humoral mechanisms that control peripheral resistance i e autonomic impulses and adreno medullary secretion as described above Thus there is a close integration of peripheral and central factors maintaining the level of the blood pressure within the normal range

In the innervation of the heart the sympathetic system mediates the accelerator impulses the vagus the inhibitory ones The carotid sinus reflex i e slowing of the heart when blood pressure rises has been mentioned already Another important reflex in the homeostatic control of blood pressure is that whereby an increased venous return to the right auricle increases heart rate

The main factors regulating the level of normal blood pressure are summarized below

SYSTOLIC

- Cardiac Output
  - Venous Return
    - Blood Volume
    - Peripheral Blood Flow
- Central Resistance
  - Elasticity of Aorta Walls
  - Capacity of Aorta

DIASTOLIC

- Peripheral Resistance
  - Caliber of Arterioles
    - Nervous Impulses
    - Humoral Agents
- Heart Rate
  - Nervous Impulses
  - Humoral Agents

2

CAUSES OF HYPOTENSION

There are many causes of hypotension but they all act in one of three ways to produce the fall in blood pressure The mechanisms of its production are (1) a reduction in blood volume (2) peripheral vascular dilatation and (3) failure of the heart or cardiogenic In most cases only one mechanism is usually involved in other cases however there may be several especially in the later phase if the hypotension is not treated properly With the exception of infection the mechanism of the manifold causes of hypotension is known and the treatment is both definitive and effective if instituted early The principal causes of hypotension are as follows

1 Reduced blood volume
   - Hemorrhage
   - Plasma loss
   - Dehydration
2 Peripheral vascular dilatation
   - Anesthesia
   - Surgical procedures
   - Drugs
   - Infections
3 Cardiogenic
   - Valvular lesions

Pericardial damage
Disturbances in rate and rhythm
Myocardial ischemia
Cardiopulmonary

3

SHOCK

CAUSES

The most common of all causes of acute hypoten sion is hemorrhage The terms shock collapse and peripheral circulatory failure have been used to describe the condition that supervenes following a reduction in blood volume The term shock itself has been qualified further depending on the circum stances of its causation as wound or traumatic shock and surgical shock It is also known as hypovolemic oligemic secondary and hemorrhagic shock

The less common causes of oligemic shock are a loss of plasma as in burns or a loss of water and electro lytes in dehydration In these conditions as in hem orrhage there is a reduction in circulating blood volume

DIAGNOSIS AND CLINICAL FEATURES

The clinical features of the fully developed state of shock are well known The patient complains of feeling cold and of insatiable thirst He is appre hensive and in pain which may not be severe The temperature is subnormal the skin feels cold and is covered with sweat Pallor and in severe shock mot tled cyanosis of the skin of the extremities is present There is a delay in filling of the vessels of the skin blanched by pressure The pulse is usually rapid and

easily compressible The blood pressure is low and may be unobtainable

Diagnosis of shock is not difficult However the recognition of the factors responsible for it is often difficult Since hemorrhage is the main factor in the great majority of cases one must know under what circumstances and to what extent blood loss has resulted in or may lead to shock

Hemorrhage may be either external or internal it may be due to injury it may occur during or following operation or it may be spontaneous The large amounts of blood that may be lost postpartum in certain operations and after severe injuries have been shown many times Blood loss from gastro intestinal lesions such as esophageal varices duodenal ulcer and carcinoma is common and may be exsanguinating

The swelling of soft tissues or the presence of dullness on percussion over body cavities is useful as an indication of the extent of hemorrhage There is a correlation between wound size and blood loss in those with trauma to the extremities A patient with 1 of his own fist s volume of tissue damaged has small blood loss with 1 to 3 moderate and between 3 and 5 a large blood loss amounting to 50 per cent of the blood volume in the first few hours of injury As a further guide to treatment it may be assumed that if the systolic pressure is below 100 approximately one third of the blood volume has been lost In an average size patient this would amount to about 1500 cc.

PHYSIOPATHOLOGY

Hemodynamics In shock due to fluid loss there is a decreased cardiac output resulting from inadequate filling of the ventricles because of a diminished venous

return There is no significant change in hemoglobin or hematocrit levels in shock from hemorrhage except hours later However when the reduction in blood volume is due to plasma loss or dehydration there is hemoconcentration early

The metabolic changes in shock are consequent to the anoxia resulting from deficient circulation There is an acidosis with a fall in CO_2 An impaired renal function is manifested by a rise in plasma NPN and a decreased formation of urine Acute renal failure the so called lower nephron nephrosis may supervene as discussed later Impairment of liver function may occur with serious consequences in terms of its role in protection against sepsis as mentioned elsewhere

Vasoconstriction Experimentally it has been shown that the kidney and the liver also contribute to the state of shock by the elaboration of humoral factors In profound shock the kidney produces a vasoconstrictor principle called VEM and the liver a vasodilator material called VDM As the animal approaches the stage of irreversible shock VDM appears in the blood in increasing amounts It has been shown to be identical with iron containing protein ferritin In animals made resistant to damage by previous graded exposures there is a decrease in the blood VDM Furthermore there is an increase in the inactivation of VDM by liver slices obtained from resistant rats The VEM VDM mechanism concerns only the smaller vessels and is a result of shock in the experimental animal

Certain compensatory phenomena accompany shock Vasoconstriction causes a pallor of the skin and contributes to the oliguria Vasoconstriction of the vessels of the skin makes blood available to more vital

regions At the same time constriction of the renal vessels may have an ultimately harmful effect on the excretory function of the kidney as described later It may mask severe hemorrhage in the earliest stages by its maintenance of blood pressure at or near the normal level

Hemodilution The other physiologic change of a compensatory nature is hemodilution As blood pressure falls extracellular fluid in the extravascular spaces *flows into the capillaries thereby increasing* the blood volume Whereas vasoconstriction and its effect on blood pressure are immediate hemodilution is a slower process taking several hours to achieve a significant effect Furthermore in dehydration hemodilution may not occur Neither of these compensatory mechanisms is effective in severe shock and never must be relied upon to take the place of treatment

CONSEQUENCES

The consequences of severe or untreated shock are several Some of the more serious of them are acute renal failure myocardial infarction cerebral thrombosis and irreversible or delayed shock Myocardial infarction and cerebral thrombosis are more likely to occur in the elderly and in individuals with coronary or cerebral arteriosclerosis

Delayed shock is a term used to describe the fatal form in which after restoration of normal blood pressure by transfusion following an initial period of severe or prolonged hypotension the blood pressure steadily declines and the patient dies although the blood volume may be normal or even above normal The cause is unknown but severe infection and

massive hemorrhage inadequately treated either separately or in combination are important contributory factors

The term irreversible shock has crept into clinical usage where it has no place It belongs in the experimentalist s vocabulary where it means that shock has been produced in such a way (amount of blood removed length of bleeding period etc) that the animal cannot recover when all the removed blood is replaced Often the term has been used to describe therapeutic failure in patients who have been treated for shock Its clinical usage should be discouraged not only for the reasons just mentioned but also because it is dangerous in that it may lead to the neglect of opportunity for effective therapy

PATHOLOGIC ANATOMY

The findings of the pathologist will seldom offer any clues at a clinicopathologic conference held to discuss the pathogenesis of the condition in cases of death due to shock Except for the typical pathologic findings of the consequences and the complications of the syndrome such as cerebral thrombosis myocardial infarction or lower nephron nephrosis there is no characteristic pathologic anatomy The organs may be pale and bloodless if transfusions were inadequate or they may be congested in those dying of delayed shock despite adequate replacement

PREVENTION OF SHOCK

It is almost an understatement to assert that surgical shock could be considered as a preventable disease The factors that have combined to bring this about are several The cause blood loss is well

known Its recognition is relatively simple Blood has become available in adequate amounts and trans fusions have been made safe

Measurement of Blood Loss The only reliable clin ical guide in the prevention and the treatment of shock is the frequent determination of blood pressure In operations in which blood loss may be severe or in patients in whom it is important that a normal blood pressure be maintained (cardiac arteriosclerotic elderly etc) the actual determination of blood loss by simply weighing the blood soaked sponges is a valuable method for estimating the amount of blood to be transfused

Anemia In many patients with chronic disease there is often an anemia associated with infection malignancy or malnutrition Such patients usually have a reduced total blood volume They withstand operation poorly and may develop shock following a small amount of blood loss if the anemia is not cor rected before operation The usual practice in such cases is to give repeated small transfusions (500 cc) of whole blood or red cell suspensions for several suc cessive days before operation

Dehydration Of equal importance is the correction of dehydration in patients about to be operated on in whom blood volume may be reduced because of vomiting diarrhea or other causes of depletion of water and electrolytes

Coagulation Defects Defects in the clotting mech anism of the blood must be sought in the history and in special cases such as jaundice actual tests for defi ciencies in coagulation must be carried out Excessive hemorrhage at operation due to such conditions as

hemophilia and hypoprothrombinemia usually can be anticipated and prevented

Anesthesia The importance of anesthesia is discussed elsewhere In the presence of existing or impending shock the choice of the anesthetic agent and its use demand great care The use of the anesthetic and oxygen are the responsibility of the anesthetist His is also the duty of detecting the early sign of shock—hypotension—by frequent determination of the blood pressure

Surgical Technic Careful surgical technic both in the gentle handling of tissue and in the use of hemostasis is important in minimizing hemorrhage The practice of leaving severed vessels to bleed by not *tying off or otherwise stopping hemorrhage should* be condemned Such practice is wasteful of blood and invites postoperative shock

Re operation A fall in blood pressure at the beginning of an operation usually is not due to blood loss It may be cardiogenic but is most likely to be due to one of the factors responsible for peripheral vascular dilatation usually anesthesia Hypotension occurring later in the operation is most often due to hemorrhage but may be due to any of the various factors mentioned and only a knowledge of the patient and the circumstances of the operation will provide the answer as to the most likely cause However when shock occurs several hours after the completion of the operation anesthesia as a cause may be excluded There remains to be considered cardiogenic causes or blood loss The most common is hemorrhage from a loose ligature a ruptured vessel undetected at operation or capillary oozing In such cases

transfusions will have only a temporary effect in re storing the blood pressure Immediate re operation must be seriously considered for control of hemor rhage in patients who develop hypotension following operation and in whom the blood pressure cannot be restored and maintained by transfusion The use of vasoconstrictor drugs may only delay the necessary and inevitable operation beyond the point of no return In elderly arteriosclerotic patients other rarer causes of hypotension such as myocardial infarction or pul monary embolism must be ruled out by clinical and electrocardiographic methods

The importance of maintaining the blood pressure as nearly as possible within the normal range before during and after the operation in patients in the older age groups is emphasized In younger indi viduals with normal cardiovascular systems a sudden and even profound decrease in blood pressure is not usually serious if it is self limited or corrected by ap propriate therapy However transient and moderate declines in blood pressure in the elderly or in those with coronary or cerebral arteriosclerosis may lead to the serious consequences mentioned previously The prevention of such accidents is the joint responsibility of internist anesthetist and surgeon Careful pre operative assessment of cardiovascular status and prep aration smooth induction and even course of anes thesia as well as the skill and the judgment of the surgeon are necessary to guide such patients safely through the stress of a major surgical operation

TREATMENT OF SHOCK

Transfusion The treatment of shock is transfusion Enough blood must be administered to restore and maintain blood volume Not only are large amounts

frequently needed but it must be given as soon as possible and rapidly The know how of transfu sion cannot be overemphasized Treatment is deter mined neither by one s impression of the amount of blood lost which is usually an underestimation nor by the large amounts which may have already been transfused but only by the response of the patient to

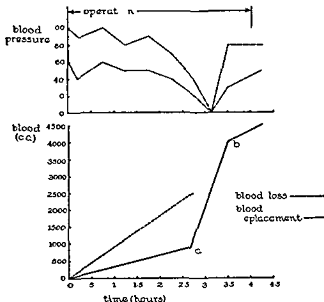


FIG 1A This illustrates (1) the large amount of blood that may be lost at operation in this case a pneumonec tomy for pulmonary tuberculosis (2) the development of shock during operation because of failure to maintain blood replacement *pari passu* with blood loss as shown in line o–a and (3) the proper treatment of shock by immediate rapid and adequate replacement of blood as shown by line a–b

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sive hemorrhage requiring large amounts of blood to restore blood pressure to normal adequate transfusions may not be given for fear of overloading the circulation Such fears are unfounded if the level of the blood pressure is taken as the guide for estimating the amount of blood to be infused Only after the blood volume and the blood pressure have been restored to normal is it likely that further transfusions will overload the circulation When the normal blood volume as reflected by a normal blood pressure has been achieved and maintained the need for rapid transfusion is no longer present Then the transfusion may be continued at a slower rate

If the patient has been overtransfused the transfusion should be stopped immediately and a phlebotomy should be performed Enough blood should be withdrawn to cause a disappearance of the signs of circulatory overloading which are a fullness of the veins of the neck râles at the lung bases and ultimately frothy sputum i e pulmonary edema

Blood must not be withheld on the mistaken notion that transfusion by raising blood pressure may increase or cause a resumption of bleeding If hypotension persists despite transfusion it indicates that the cause is other than or in addition to blood loss e g myocardial infarction Transfusions must be continued until the bleeding has been controlled in those cases in which shock is due to continuing blood loss

Intravenous Transfusion Usually transfusion is given into the veins of the antecubital fossa but any accessible one may be used In massive or continuing hemorrhage it may be necessary to transfuse into sev

eral veins simultaneously and to increase the speed of the transfusion by applying pressure to the flow of blood from the transfusion bottle In the severely shocked patient with cold extremities and collapsed peripheral vessels it is necessary to do a cut down at once without losing valuable time searching for veins in the usual locations

INTRA ARTERIAL TRANSFUSION Sometimes intra arterial transfusion via the radial artery is used when resuscitation by intravenous transfusion fails However evidence is accumulating that it is not the route but the rate of transfusion that is the important factor in treating the severely shocked patient

Ancillary Measures Besides transfusion other ancillary measures are used The control of hemorrhage is obviously of prime importance Pain and apprehension are allayed by morphine 10 mg (gr 1/6) given intravenously rather than intramuscularly because of the impaired absorption due to circulatory depression The morphine may be combined with 10 mg barbiturate

To combat infection antibiotics should be given especially if shock is due to injury of the abdominal cavity or perineal region A good combination is penicillin 1 000 000 U and streptomycin 1 Gm repeated at 6-hour intervals

Vasoconstrictor drugs such as norepinephrine are useful in certain cases where peripheral vascular dilatation contributes to the reduced blood volume e g hemorrhage with sepsis

Body temperature should be maintained but the excessive application of heat should be avoided because it causes vasodilatation

Except in those cases with cerebral or cardiopul monary complications or injuries patients in shock should be placed in the head low position to shift blood from the lower parts of the body thereby in creasing the circulation to the vital organs the brain the heart the liver and the kidneys Patients in shock should be moved as little as possible to mini mize the stimulation of peripheral vasodilatory re flexes

LABORATORY ASPECTS OF TRANSFUSION

The treatment of hemorrhagic shock with transfu sion and the importance of administering the blood as soon as possible after blood loss rapidly and in sufficient amounts have been discussed previously Without describing in detail the laboratory aspects of transfusion i e collection preservation grouping crossmatching of blood certain ones should be men tioned Only group specific blood may be used i e group A Rh negative blood for a group A Rh negative patient In some instances of limited supplies of blood or emergency situations group O blood can be given to individuals of any group and those who belong to group AB may receive blood of any group Only Rh negative blood may be given to Rh negative females to minimize the possibility of incompatible transfusion reaction and hemolytic disease of the new born

The responsibility of the laboratory staff in the per formance of the necessary tests prior to transfusion is unique in laboratory medicine The results of most laboratory tests are used to corroborate a clinical diag nosis Any discrepancy between the clinical and the

laboratory findings can be checked by repeating the tests or taking a new look at the patient before treatment is begun However an error in technic interpretation or labeling by the staff of the transfusion service may result in a serious or even fatal transfusion reaction

TRANSFUSION REACTIONS AND COMPLICATIONS

The incidence of transfusion reactions and their occurrence in spite of the greatest care in collecting grouping crossmatching and transfusion of blood afford a constant reminder that transfusions should be administered only when definitely indicated

Incompatible or Hemolytic Reaction The most serious of all is that known as an incompatible or hemolytic reaction which occurs when a patient gets the wrong blood (usually a group O patient receives group A blood) It is due much more often to carelessness by those responsible for administering the blood rather than to laboratory errors

Symptoms The symptoms are chill increased temperature and pulse restlessness dyspnea pain in the chest or the lumbar region and circulatory collapse followed later in severe cases by jaundice and renal failure Since the earliest manifestations are those complained of by the patient e g a feeling of chilliness or pains in the back extra care must be exercised in giving transfusions to those under general anesthesia

Pathogenesis The pathogenesis of the renal failure known as lower nephron nephrosis that may follow a hemolytic transfusion reaction is probably similar to that of profound or prolonged shock The

factors involved may be summarized as lowered blood pressure vasoconstriction of renal vessels and a reduced renal blood flow

TREATMENT may be divided into the following phases (1) The importance of preventing such accidents by constant vigilance to make sure that the patient gets the right blood (2) If in spite of such efforts the patient gets the wrong blood a knowledge of the clinical features of a reaction should lead to an immediate cessation of the transfusion if there is someone by the side of the patient who will recognize the reaction and stop the transfusion If in doubt that a transfusion reaction is taking place stop the transfusion (3) After having stopped the transfusion determine if it really is a hemolytic reaction by obtaining a specimen of the patient s blood and sending it to the laboratory for regrouping and crossmatching (4) The patient should be given sodium lactate to alkalinize the urine and should receive glucose to provide fluid for diuresis (5) During the last phase the aim of treatment is to maintain a balance between fluid intake and output and the acid base equilibrium until renal function returns to normal Until such time it is important not to force fluids otherwise pulmonary edema may develop A useful rule is to give every 24 hours an amount equal to that excreted in the previous 24 hours plus 500 to 1000 cc. for insensible loss

Pyrogenic Reactions The incidence of pyrogenic reactions has been greatly reduced since the introduction of disposable donor and transfusion sets which are pyrogen free The symptoms are those of a hemolytic reaction The treatment is to stop the transfu

sion Since it is impossible on the basis of symptoms to differentiate between a pyrogenic and a hemolytic reaction all reactions following the transfusion of whole blood or red cell suspensions should be re garded as due to incompatibility until proved to be otherwise

Allergic reactions sometimes occur The usual man ifestation is urticaria They are not serious The treatment is symptomatic

Edema There is no evidence that even in large transfusions of 10 or more bottles of blood given over a short period of time the citrate has any toxic effect or causes a clinically significant change in the coagu lation of the recipient s blood However the sodium radical which is not excreted rapidly may cause water retention and pulmonary edema In large transfu sions in the elderly or those with cardiorenal disease this complication must be guarded against Intra venous solution of saline should be used sparingly in such patients who are receiving large amounts of blood Since the ratio of diluent to blood is approxi mately 1 to 3 a transfusion of 4 liters contains slightly more than 1 liter of diluent with about 20 Gm of sodium citrate

In such patients it may be beneficial to use 1 bot tle of packed cells for every 3 or 4 bottles of whole blood to avoid circulatory overloading and pulmonary edema If pulmonary edema develops treatment by immediate phlebotomy is expedited by using a blood donor bottle of the vacuum containing kind

Embolism caused by the introduction of air in the transfusion never should occur It is necessary to use specially prepared transfusion sets containing fine

mesh filters to remove particulate matter which might be the cause of embolism in transfusing whole blood packed cells or plasma

Jaundice There are three causes of jaundice following transfusion (1) hemolysis of donor cells prior to transfusion (2) hemolysis of donor cells after transfusion due to incompatibility and (3) homologous serum hepatitis

PRETRANSFUSION HEMOLYSIS The least important in its clinical implications is that due to hemolysis of the donor cells either before or immediately after transfusion The hemolysis is due to the early death of the cells because of improper storage or handling of blood i e their life span has been so shortened that the cells are moribund when they are transfused Blood is taken out of the blood bank to the wards or the operating theater It may be left standing at room temperature for several hours and then returned unused The same blood may be crossmatched again and taken out for another patient If this sort of thing happens 2 or 3 times and the blood has not been cared for properly the red cells reach senility earlier than the date of obsolescence stamped on the bottle When such blood is transfused massive hemolysis and jaundice may occur There are usually no other manifestations such as precede the appearance of jaundice in the next type to be discussed The prevention of this complication is the responsibility of everyone who orders a blood transfusion or handles a bottle of blood

POST TRANSFUSION HEMOLYSIS *Causes of Jaundice* By far the most important of the causes of jaundice following transfusion is known as the hemolytic or

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utmost importance in transfusing such patients that the Rh type be determined accurately and blood transfused only after crossmatching

Rare Factors and Multiple Transfusions The last group of incompatibilities is that due to a combination of rare factors (e g Kell) and multiple transfusions The recipient whose cells do not contain one of the factors is given by chance blood that does have that particular factor he develops antibodies to it and during a subsequent transfusion of blood containing the same factor he has a hemolytic reaction

This may also happen to an Rh negative patient who receives multiple transfusions of Rh positive blood However when supplies of Rh negative blood are limited it may be justifiable to transfuse male patients with Rh positive blood if transfusion is imperative but with female patients the risks of such a procedure must be weighed more carefully (As mentioned already Rh positive blood cannot be given under any circumstances to a patient who has antibodies to the Rh factor) Rh positive blood given to an Rh negative female may sensitize her so that even years later in her first pregnancy the infant if Rh positive may have hemolytic disease It may also be dangerous to transfuse the Rh negative woman with Rh positive blood in large amounts for if she ever has been sensitized during pregnancy she may respond to the transfusion with the production of antibodies sufficient to hemolyze the transfused cells and cause jaundice

To prevent this type of jaundice it is necessary that the laboratory be informed if the patient is a recipient

of multiple transfusions because incompatibilities due to such factors can be detected only by special grouping and crossmatching procedures

Homologous Serum Jaundice Finally the third cause of jaundice is not a hemolytic process but a hepatitis which is caused by a virus transmitted in the blood the plasma or the serum of the donor Although the morbidity is low the mortality is high It may be differentiated from the preceding type of jaundice by its late appearance on an average of 60 days following transfusion and by the various tests used to distinguish between hemolytic and nonhemo lytic jaundice The prevention of the disease is ren dered all the more difficult because of (1) the preva lence of carriers who are also actual or potential blood donors (2) the absence of any test for the ex *clusion of such donors and (3) the lack of any method for destroying the virus in bank blood The blood* derivatives albumin gamma globulin and fibrinogen have been rendered free of the virus in their prepa ration recent reports would indicate

BLOOD DERIVATIVES

Red Cell Suspensions Besides whole blood various fractions and products of whole blood are available They may be preferable or supplementary to whole blood in certain conditions Red blood cell suspen sions or packed cells as they are often called are use ful in the treatment of hemorrhage in the elderly or in those with cardiorenal or cardiopulmonary disease In such patients the use of whole blood in large amounts because of the contained diluent of anti coagulant and preservative may overload the circu lation Packed cells which contain only a minimal

amount of diluent may be used to increase the hemo globin content of the circulating blood without the addition of excess amounts of fluid Usually they are prepared by allowing the blood to stand undisturbed for several hours and drawing off the supernatant plasma or they may be obtained more quickly by centrifuging If means are not available for the ster ile preparation of packed cells they may be obtained by standing the transfusion bottle head down for several hours and after the cells have settled admin istering only the first half of its contents In trans fusing packed cells the same precaution in respect to sterility freshness compatibility etc should be observed as for whole blood Their preparation has been simplified by the introduction of the Fenwal blood pack

Platelet Suspensions The treatment of shock due to hemorrhage resulting from deficient platelets has been improved recently by the introduction of meth ods for the preservation of platelets for transfusion Even fresh blood drawn in the ordinary way contains no appreciable number of thrombocytes Hemor rhage from thrombocytopenia is often uncontrollable by ordinary transfusions If blood is drawn into plastic bags or glass containers coated with silicone the platelets may be preserved long enough to effect cessation of bleeding in such cases provided that the blood is transfused immediately A simple procedure used at the Royal Victoria Hospital is as follows (1) the patient s blood is grouped (2) a blood sample is obtained from a donor of the same group as the pa tient (3) the donor s and the patient s blood is cross matched (4) if compatible the donor is bled into a Fenwal plastic bag or a Baxter bottle coated with

silicone (5) the patient is transfused immediately after the donation has been completed

Plasma In addition to the cellular components of blood used in the treatment of hemorrhage there are several plasma fractions that are useful

Albumin was prepared for the United States Armed Forces during World War II for the emergency treatment of shock It is a valuable substance for this purpose since it is the plasma protein which normally maintains colloid osmotic pressure in the blood Its administration provides a rapid method of treating shock because it quickly shifts extravascular fluid into the circulation It must be used with extreme caution in patients suspected of being dehydrated and in such patients its use must be accompanied by intravenous saline In the concentration commercially available for intravenous use it is five times as effective as an equal amount of plasma i e 100 cc of albumin is equivalent to 500 cc of plasma as a plasma expander Albumin is also used to reduce cerebral edema and to provide metabolic requirements in severe burns

Fibrinogen The remaining plasma protein fraction used in transfusion treatment of hemorrhage is fibrinogen More and more cases of bleeding due to a coagulation defect resulting from hypofibrinogenemia are being reported Fibrinogen administration is often the only means of restoring the fibrinogen level to normal and correcting the coagulation defect in such cases The diagnosis of hypofibrinogenemia must be considered in the presence of hemorrhage occurring in cases of metastic carcinoma of the prostate and the pancreas severe liver disease toxemia

and Rh isosensitization with a dead fetus It is also to be suspected in severe hemorrhage occurring dur ing major lung surgery The most important how ever from all aspects is premature separation of the placenta

Clinically the condition should be suspected in obstetric patients who continue to bleed from the vagina despite repeated transfusions of even freshly drawn blood and other measures usually employed to stop hemorrhage The patient s blood can be tested for fibrinogenopenia by the following procedure (1) with draw 3 cc of blood (2) incubate at 37 for 30 min utes (3) if no clot appears the fibrinogen level is at a critically low level Fibrinogen is now commercially available as Parenogen supplied by Cutter Labora tories Every maternity hospital should maintain an adequate stock for emergency use Usually bleeding can be controlled by the infusion of 4 mg

BLOOD SUBSTITUTES

Originally called blood substitutes it is now custom ary to refer to the substances which increase blood vol ume as plasma expanders extenders or augmenters There is no substitute for blood when large amounts are needed However in cases where amounts rang ing from 500 to 1500 cc of blood are ordinarily used plasma expanders may be substituted for blood In emergency situations their use is often a life saving measure during the time necessary to start a transfu sion Their use in these circumstances justifies their being called blood substitutes

They comprise a variety of substances of animal or plant origin or synthetically produced They all have

a common physical property similar to that of albumin—of holding fluid in the vascular system Dextran is a polysaccharide derived from the fermentation of sucrose Polyvinyl pyrrolidone (PVP) is a synthetic polymer made from acetylene Gelatin is derived from an animal and pectin from a plant source

They are all reliable and safe substitutes Clinical experiences with these substances have demonstrated that they do not give rise to reactions of any kind Recently it has been found that following the administration of more than 1000 cc of Dextran in any one infusion there may be an increased bleeding tendency as revealed by laboratory studies It has not been shown to be of clinical significance and the exact mechanism is unknown

They restore and maintain blood pressure in cases in which blood loss does not exceed 1500 cc In patients with severe or prolonged bleeding as mentioned previously it is necessary to use whole blood Even in such cases however they may be used to supplement limited supplies of blood

In many cases a substitute alone will prevent shock Most blood transfusions are given for operations requiring from 500 to 1500 cc of blood replacement It is in this type of case that the substitutes have an important role as blood sparing agents

They have other advantages too Their use will lessen the incidence of serum hepatitis due to transfusion of blood containing the virus of the disease Similarly the incidence of reactions due to transfusion of incompatible or contaminated blood will be decreased The danger of sensitization to the Rh and related factors by blood transfusion in female patients

and the development of hemolytic disease of the new born is also reduced

PLASMA LOSS

Burns Reduction of the blood volume from loss of plasma most commonly occurs in cases of burns The loss of plasma from the damaged capillaries in the burned regions of the body leads to an actual reduction in the blood volume The injury also produces psychic and physical stimuli that cause peripheral vascular dilatation and a reduction in effective blood volume

Hemoconcentration is a constant feature of severe burns The determination of the degree of hemoconcentration by hemoglobin or hematocrit studies is of great value in estimating the reduction in plasma volume and the amount of plasma to be transfused Hemoconcentration studies as a guide to therapy are likewise of value in other conditions in which a reduction in blood volume is that of plasma loss or loss of water and electrolytes

Crush Syndrome A condition in which shock is usually present accompanied by hemoconcentration is the crush (compression traumatic) syndrome which follows compression injuries to the extremities When the compression is released plasma transudes into the tissue from damaged capillaries distal to the compression

Acute Purulent Exudation Shock due to a reduction in plasma volume is also to be found in conditions in which there is acute purulent exudation such as empyema and peritonitis A rare condition in which plasma loss may be considerable is pemphigus

In intestinal obstruction especially when accompanied by local circulatory stasis as in mesenteric thrombosis there may be a diffusion of plasma into the peritoneal cavity and the bowel lumen with resultant reduction in plasma volume

Obstruction In strangulating obstruction of the small bowel particularly if it involves a large segment reduction in blood volume may be great Moreover distension of the abdomen may impede the venous return from the lower extremities Dehydration due to vomiting present in such cases is also an important factor contributing to the reduction in plasma volume

Treatment The treatment of shock due to these causes is the infusion of plasma The various plasma substitutes described have been used with good effect In the treatment of severe burns blood transfusion also should be given because of the anemia which becomes manifest when the hemoconcentration disappears Intestinal obstruction must be treated with saline infusion as well as plasma to replace the fluids lost by vomiting

DEHYDRATION

A reduction in blood volume occurs in dehydration Loss of water and electrolytes in excessive amounts *from the skin the gastro intestinal tract or via the* kidneys and insufficient intake of fluid give a clinical picture characterized by dryness of the mouth flushed skin *increased temperature oliguria and low blood* pressure Hemoconcentration is usually present but may be masked by the coexistence of anemia Especially in the elderly there may be psychologic changes with restlessness delirium stupor or excitement Salt

depletion may be extreme from vomiting diarrhea gastro intestinal fistula and gastric suction In the low salt syndrome sometimes occurring in patients with congestive heart failure treated with mercurial diuretics in diabetic coma and in adrenocortical in sufficiency circulatory collapse may be profound De hydration in infants and children may be rapidly fatal

Treatment The correction of the electrolyte im balance that may result from dehydration is often more difficult than the correction of the dehydration itself The clinical biochemical aspects of the prob lem such as the tendency for an acidosis to develop if sodium is lost in excess of chlorides (pancreatic ileal jejunal secretion and urine) or for an alkalosis to develop if chloride is lost in excess of sodium (gas tric secretion) lie outside the scope of the present dis cussion However the treatment of dehydration re solves itself into the restoration of reduced blood vol ume by intravenous infusion of NaCl in the first in stance and only later in the correction of electrolyte imbalance by the use of modified solutions

Isotonic NaCl or normal saline probably is given most frequently It is used for patients with dehydra tion resulting from vomiting and in those in whom it is necessary to replace aspirated gastro intestinal fluids Hypotonic NaCl infusion is used in simple water deprivation in hypoalbuminemia and in any condition where the immediate need is water replace ment without increasing the osmotic pressure of the plasma or raising the serum sodium level Such a solution is obtained by the simultaneous infusion of a solution of dextrose in water and normal saline

Hypertonic NaCl is used in conditions such as the

low salt syndrome in which the large volume of isotonic solution required to raise the low sodium level might cause circulatory overloading This solution because of its hypertonicity draws water from the intracellular into the extracellular tissue causing dehydration of the cells if impaired renal function does not permit the excretion of excess sodium For these reasons hypertonic saline solutions must be used cautiously

SOLUTIONS CONTAINING POTASSIUM such as Ringers Hartmans Darrows are used for treatment of dehydration due to diarrhea or other conditions in which there is a loss of secretion from the lower gastrointestinal tract and in diabetic acidosis In such cases there is a loss of potassium of significant amounts in addition to the loss of other electrolytes Other intravenous solutions containing all the electrolytes found in normal human plasma i e sodium chloride calcium magnesium and potassium have been introduced recently

4

PERIPHERAL VASCULAR DILATATION

The nervous regulation of vascular tone through out the whole circulatory system or any of its parts may be interfered with by a variety of agents drugs procedures infections psychic and other stimuli to produce vasodilatation and resulting hypotension They are mediated by one of two mechanisms either inhibition of vasoconstriction or initiation of vasodilator activity or both In the past hypotension due to vascular dilatation has been called neurogenic or primary shock

ANESTHESIA

Next in importance to hemorrhage as a cause of hypotension during surgery is the anesthesia itself Anesthetic agents besides blocking painful stimuli and relaxing the musculature have certain unde sirable effects paralysis of vasomotor tone interfer ence with the conduction mechanism of the heart and the deleterious effects of anoxia on the myocar dium and the medullary centers controlling circula tion and respiration

Preanesthetic Medication Either because of an in creased sensitivity of the patient or an overdosage preanesthetic medication with avertin barbiturates morphine etc may cause a lowering of the blood pressure Operation should be deferred in such cases until the blood pressure rises of its own accord or is restored to normal with vasoconstrictor drugs if im mediate operation is imperative

Ether and Pentothal Sodium Rapid induction with ether or Pentothal Sodium may produce hypoten sion due to uncompensated peripheral vasodilatation Lightening the depth of anesthesia usually suffices for the return of the blood pressure to normal levels Or it may be necessary to interrupt the anesthesia for a short time and administer oxygen under pressure As a general rule vasopressors are used with conduction anesthesia

Cocaine when used as a local anesthetic has been known for years as a potentially dangerous drug be cause of the collapse and even death that occasionally followed its use Now it is rarely used except as a topical agent in weak concentrations and combined with a vasopressor in eye operations and broncho-scopic examination

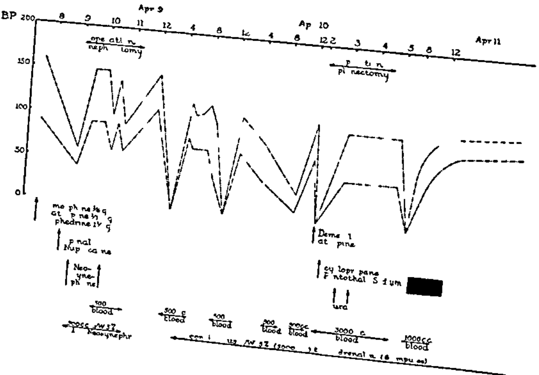
Pituitrin preparations have been reported to cause a severe fall in blood pressure in patients anesthetized with cyclopropane Care must be taken not to inject oxtocin or other pituitrin preparations in obstetric patients until after the anesthesia has worn off

With these as with all other anesthetic agents and premedication drugs it must be remembered that they interfere with the normal balance between vasocon strictive and vasodilator influences on the one hand

and on the other the reflexes which slow or increase the heart rate There sometimes results an increase but more often a decrease in blood pressure Of the two hypotension is by far the more important The significance of the various forms of tachycardia brady cardia and other arrhythmias is considered later

Spinal Anesthesia Spinal anesthesia (pontocaine etc) causes a reduction in blood pressure because of the paralysis of the vasomotor mechanism with dilata tion of the vascular bed below the level of anesthesia The time of appearance of hypotension due to this mechanism is usually shortly after the induction of anesthesia either before or at the beginning of the operation The prevention and the treatment of hypotension due to spinal anesthesia depends on the use of ephedrine gr 3/4 to 1 1/2 before the spinal puncture is made and a vasopressor drug such as neo synephrine or norepinephrine if hypotension develops following injection of the anesthetic drug As men tioned elsewhere epinephrine is not used because of its harmful effects on the heart in susceptible indi viduals or in those anesthetized with cyclopropane or related anesthetic agents

Cyclopropane has been shown to cause the most sudden and dangerous of all forms of hypotension namely that of ventricular fibrillation and cardiac standstill Its mode of action is considered to be due to its sensitization of the heart to irregularities in duced by reflex stimulation via the autonomic nerv ous system or by the direct action of epinephrine on the cardiac conduction system Trichlorethylene and ethyl chloride may act in the same way as cyclopropane to produce cardiac irregularities Chloroform



BP
200
150
100
50
0
Apr 9
Ap 10
Apr 11
8
9
10
11
12
4
8
4
8
12
2
3
4
5
8
12
Neo-
blood
500 c
blood
3000 c
blood
1000cc
blood
Deme
ura

FIG 24 This illustrates (1) shock following spinal anesthesia and its treatment with Neosynephrine (2) the development of shock after operation in this case a nephrectomy for left renal calculi (3) the failure of blood transfusion to maintain blood pressure (4) the necessity of reoperation to look for and control bleeding in this case a ruptured splenic pedicle torn during the nephrectomy (5) the development of shock following the second operation due to insufficient blood replacement

content of blood returns to normal the stimulation ceases and the blood pressure falls

As already discussed incompatible transfusions may cause collapse The early symptoms of such a reaction e g pain in the back and a feeling of chilliness will be absent if the patient is unconscious from a general anesthetic but the presence of a chill will warn that a transfusion reaction may be taking place However if both a general anesthetic and a muscle relaxing drug such as curare have been used there will be none of the usual symptoms (pain) or signs (rigor) of an incompatible transfusion reaction Under these circumstances however tachycardia tachypnea an increased bleeding tendency or a fall in blood pressure may indicate that an incompatible blood is being transfused But they are unreliable manifestations it is better to rely on extra precautions to make certain that the proper blood is administered to such patients

SURGICAL PROCEDURES

Position of Patient There are surgical procedures and manipulations during operation that of themselves cause a fall in blood pressure apart from blood loss and anesthesia Stimulation of vasodepressor reflexes induces vasodilatation and hypotension Posturing the patient in certain positions as in the use of the kidney bar or the jacknife position may cause a drop in blood pressure which may be corrected by change of posture and the injection of a vasoconstrictor drug

Visceral Manipulation Operations on the thoracic,

the abdominal or the pelvic organs also may cause reflex vasodilatation and a lowering of blood pressure The hypotension is not related to the slowing of the heart which is a secondary response to the vasodilatation The decreased blood pressure due to these factors is usually *transient and self limited* However in the presence of other causes of hypotension such as hemorrhage these reflexes through their additive effect on the blood pressure may assume unusual importance It can be corrected by the use of vasoconstrictors

In operations on the neck during intubation or during thoracentesis the vasovagal reflex may be activated as shown by a slowing of the pulse and a fall in blood pressure Unlike the peripheral vascular type just described it is of cardiogenic origin and may be prevented or abolished by atropine and similarly acting drugs which prevent the vagus from responding to such stimuli

During operations for the removal of a pheochromocytoma or a diseased kidney causing hypertension *hypotension may result because of the sudden cessation* of secretion of epinephrine or hypertensin In such operations it is now routine to use norepinephrine or other vasopressor drugs during the operative and the immediate postoperative periods

Interference with Vasoconstrictor Mechanism In patients undergoing the second stage of sympathectomy and splanchnicectomy for hypertensive cardiovascular disease hypotension during the operation may result from interference with the vasoconstrictor mechanism of the lower spinal segments unless a vasopressor agent is used It is frequently necessary in

such patients to continue the intravenous administration of norepinephrine or similar drugs during the postoperative period to prevent a fall in blood pressure due to uncompensated vascular dilatation in the lower limbs

Vasopressor Drugs As this and preceding sections have shown the vasopressor drugs are very valuable antishock substances In certain conditions such as those just described and during spinal anesthesia they are specific antagonists to shock In others such as hemorrhage they may be useful adjunctive agents In still others such as myocardial infarction severe infection etc to be discussed later they may be of benefit and should be used to treat the accompanying shock

ADRENOCORTICAL HORMONES IN TREATMENT OF SHOCK

These substances have special value in the treatment of shock in the following circumstances (1) operations involving removal or interference with secretion of pituitary and adrenal glands e g Cushing s disease (2) operations on patients who have been under long term treatment with cortisone and (3) Addison s disease In the first type of case the sudden withdrawal of adrenocortical secretion may precipitate collapse In the second type patients whose adrenocortical activity has been suppressed by long continued treatment cannot respond to the sudden increased demand of the added stress of operation Peripheral circulatory collapse and hypoglycemia result In both cases treatment consists of giving cortisone in adequate doses from 100 to 200 mg daily before and

after operation gradually reducing the dosage in the postoperative period During operation it may be necessary to treat with intravenous cortisone Blood transfusions and vasoconstrictors are also indicated

The occurrence of collapse in patients with adrenocortical insufficiency when infection or trauma supervenes is treated with cortisone intramuscularly and intravenously As mentioned above shock may also occur in patients under long term treatment with cortisone who develop infection or receive an injury or undergo an operation Such an eventuality must be guarded against in patients with arthritis asthma dermatitis or others receiving cortisone for long periods Evidence of its use must be specifically sought in taking the history of such patients prior to operation Under such circumstances as well as during the course of any intervening illness the cortisone should be increased In all such cases when shock is either present or may be anticipated it is well to support the circulation by using norepinephrine or other vasoconstrictors and to give blood transfusions or other blood volume expanders during the critical phases

Patients who are chronically ill may not show an adequate response to an added stress In rare instances in those with an undetected adrenocortical insufficiency the stress of illness injury or operation may also cause collapse The diagnosis in such cases can be confirmed by determining the eosinophilic response But except in these and the previous cases mentioned where cortisone is specifically indicated it has no use in the prevention or the treatment of shock

ABDOMINAL EMERGENCIES

Many patients with signs of an acute abdomen have in addition the signs of shock The collapse may be extreme in those with infection of the peritoneal cavity as described later But even in patients with early minimal or absent peritoneal contamination signs of shock are usually present Perforation of a viscus e g ruptured duodenal ulcer empyema of the gallbladder acute peritonitis splenic infarction etc usually are accompanied by collapse Other visceral disturbances in which shock may be a prominent feature are torsion of a testicle renal or ureteral colic a twisted ovarian cyst *In all of these conditions* the treatment of the collapse is the treatment of the underlying condition by surgery vasoconstrictors antibiotics and infusions of blood and fluid

INFECTION

Wounds The profound effects of contaminated wounds especially those of the abdominal cavity on the blood pressure of severely injured casualties has been known since World War I and intensively studied since World War II In such cases collapse may *be severe despite minimal reduction in actual blood* volume and may persist even after adequate replacement as measured by blood volume determinations

Bacteremia Peripheral circulatory collapse also may occur in various fulminating infections accompanied by a bacteremia with the pneumococcus meningococcus streptococcus and gram negative bacilli The severe shock that is usually fatal following transfusion with contaminated blood or plasma belongs in this category The circulatory depression fre

quently found in cases of peritonitis and intestinal obstruction in spite of correction of fluid balance is probably of a similar nature

Although the mechanism of the vascular collapse is still uncertain it is thought to be due to peripheral vascular dilatation in which the venules are chiefly involved It has been shown that it is not due to reduced blood volume It is not considered to be due to cardiac impairment although a direct action on the heart as well as on the peripheral vasculature by the bacterial toxins cannot be excluded

TREATMENT is most unsatisfactory The use of wide spectrum antibiotics early and in large amounts (e g Penicillin with Streptomycin) may be helpful and always should be instituted The replacement of blood plasma water and electrolytes in cases in which blood volume is reduced by a loss of one or *more of these constituents of the circulation is extremely important* *Vasoconstrictors may be of benefit* and always should be administered

Contaminated Infusion Fluids The prevention of shock due to the infusion of contaminated blood or plasma requires special mention Since the danger of contaminants is always present blood or plasma should be used only when indicated Blood before being administered should be checked for hemolysis and for a characteristic vermilion hue imparted to *the inner surface of the bottle on shaking which indicates* contamination

The use of plasma stored in the liquid state is fraught with the danger of shock Not only may it be impossible to recognize contaminated plasma but even plasma stored in the cold may contain contami

nants that grow at low temperatures The use of dried or frozen plasma reconstituted or thawed im mediately before being used and the plasma expand ers as discussed elsewhere will minimize the incidence of shock due to contaminated plasma

The preparation of plasma and red cell suspensions demands the most careful technic and sterile precau tions since these materials which are excellent bac terial culture media may be stored for a considerable period before being used If a transfusion for any reason has to be stopped a safe rule to follow is that the same bottle of whole blood plasma red-cell sus pension or any other intravenous solution should not be used again if more than an hour has elapsed be tween the first attempt and the next because of the danger of contamination

DRUGS

Hypertension Drugs recently introduced for the relief of hypertension may produce in some instances marked lowering of the blood pressure They may be classified according to their mode of action as (1) the ganglionic blocking agents tetraethyl ammonium and Hexamethonium (2) centrally acting sympathetic drugs hydralazine (Apresoline) dihydroergocornine (DHO) and Veratrum (3) peripherally acting sym patholytic depressants Dibenamine and Priscoline The final common pathway of action of all of these drugs (and sodium nitrate) is peripheral vascular paralysis The vasomotor collapse responds to the vasoconstrictor drugs such as norepinephrine Be cause of its cardiac effects and the underlying cardiac disease that may be present in cases in which these

hypotensive drugs are used epinephrine is contra indicated

Barbiturate overdosage and poisoning with o her drugs or toxic agents is almost invariably accompa nied by collapse The treatment of the collapse is as important as the removal of the drug by stomach washing or neutralization of its effect with an anti dote Although there is no reduction in actual blood volume blood transfusion in addition to the use of vasoconstrictors may be life saving Oxygenation of the tissue must be achieved not only by restoring the circulation but also by artificial respiration

Anaphylactic reactions of which hypotension is a manifestations may be so rapidly fatal that no treat ment is of any avail However in many instances they can be prevented Penicillin is known to cause such reactions when given by injection to allergic individuals Manifestations of allergy always should be inquired into before injection of any drug or for eign substance whenever possible In the case of penicillin its oral rather than intramuscular admin istration is the one of choice When a drug an anti biotic a foreign serum or any agent that may cause such a reaction is used epinephrine always must be at hand ready for instant use to counteract the fall in blood pressure

CONTROLLED HYPOTENSION DURING SURGERY

The use of controlled hypotension during surgery has been recommended by some anesthetists as a val uable method in suitably selected patients undergoing certain operations The advantages according to its advocates are that hemorrhage is lessened thereby

permitting more rapid technic and a better view in a relatively bloodless field

Induction There are several means of inducing hypotension which may be used Spinal anesthesia and Hexamethonium paralyze the vasoconstrictors of the lower spinal segments Hypothermia by refrigera tion or phenothiazine derivatives is also used Besides the possible harmful effects of hypotension the pheno thiazine drugs such as Largactil may cause liver dam age Still another method of reducing blood pressure is by phlebotomy or rather arteriotomy whereby the patient is bled into a closed system the blood can be reinfused quickly if the need arises If this method is used the patient must be postured in the head-down position and blood replacement must keep step with blood loss Because of the removal of the normotensive homeostatic mechanism of vasoconstriction when spinal anesthesia or Hexamethonium are used tilting the patient into the head up position by caus ing a further pooling of blood in the lower part of the body may further reduce the blood pressure to dangerously low levels The loss of even small amounts of blood may have a similar effect

Complications The major complications of this form of preventing blood loss during surgery are reactionary hemorrhage from bleeding vessels not de tected and ligated at operation acute renal failure thrombosis of cerebral coronary or retinal vessels leading to hemiplegia myocardial infarction or blind ness and death The contraindications are many and include the elderly arteriosclerotic hypotensive or hypertensive individuals and all patients in whom it may be anticipated that blood replacement and oxy

genation may be difficult or in whom blood loss may be large Even its proponents point out that it is a potentially hazardous method which should only be used in carefully selected cases by skillful and experienced anesthetists

ORTHOSTATIC HYPOTENSION

A clinical entity characterized by orthostatic hypotension vertigo hypohydrosis impotency bladder dysfunction and relatively slow cardiac rate has been described This is considered to be due to disturbances in the autonomic nervous system as manifested by the impairment in both vasoconstrictor and vasodilator components The hypotension is a reflection of the failure of vasoconstriction in some parts of the body to compensate for vasodilatation in others and also to the absence of reflex tachycardia The lesion responsible for the defect in autonomic function is thought to be situated in the hypothalamus

Postural hypotension may occur also in patients with organic nervous diseases such as myasthenia gravis neurovascular syphilis subacute combined sclerosis and the various neuropathies due to vitamin deficiency Specific treatment of the disease process itself and symptomatic treatment of the hypotension by the usual measures of abdominal binders and elastic stockings should be undertaken The increase of blood volume by increased daily intake of sodium chloride and the use of vasoconstrictor drugs such as ephedrine may be helpful

Other forms of orthostatic hypotension include those due to large varicosities or angiomata of the extremities and phlegmasia dolen caerulens Stand

ing for long periods of time without moving the muscles of the legs sufficiently to aid the return venous flow may cause a severe fall in blood pressure with *syncope* In the aged and those convalescent from a long or debilitating illness orthostatic hypotension may result from the deficient support to the vasculature afforded by the weakened musculature Treatment consists of progressive exercises abdominal binders and ephedrine

5

CARDIOGENIC HYPOTENSION

Hypotension resulting from a reduced cardiac out put secondary to diminished venous return (second ary shock) or reduced peripheral resistance (primary shock) has been discussed already A third cause of sudden lowering of the blood pressure is that due to the heart itself Cardiac output may fail because of permanent structural changes due to disease processes (rheumatic fever arteriosclerosis etc) or transient functional influences (anoxia during anesthesia tachy cardia etc)

ENDOCARDIAL CAUSES

A sudden fall in blood pressure due to aortic or mitral stenosis may occur during exertion or the stress incident to surgical operation The increased meta bolic demands of the body are met ordinarily by an increase in the blood supply to the tissues through an increase in both peripheral vasodilatation and car diac output However in aortic or mitral stenosis the cardiac output cannot increase because of the im pediment to the flow of blood through the constricted valves The increased peripheral vasodilatation re mains unopposed and hypotension ensues

Furthermore in patients with aortic or mitral steno-

sis reflex *tachycardia* brought on by such stimuli as exertion and operative procedures (intubation visceral manipulation etc) shortens the diastolic filling time Diminished cardiac output results which in turn leads to a fall in blood pressure

The recognition of this cause of hypotension during surgery depends on an adequate preoperative history and physical examination The occurrence of syncope on exertion and the presence of the characteristic systolic thrill and murmur at the base of the heart are the principal diagnostic features The murmur of aortic stenosis is heard best at the end of expiration with the patient leaning well forward

In patients with mitral stenosis the characteristic apical diastolic murmur and a history of rheumatic fever are rarely absent In contrast with those with aortic stenosis it usually occurs in the younger age group

Treatment When blood pressure falls during operation in such patients it may be restored by (1) measures which increase *peripheral resistance* i e *norepinephrine* and (2) those which decrease heart rate such as prostigmine The latter drug augments the influence of the vagus in slowing the heart Atropine scopolamine and similarly acting vagal depressant drugs should not be used preoperatively Pain apprehension anxiety and excitement which increase the heart rate should be avoided and such stimuli eliminated by the use of morphine and barbiturates preoperatively

Many patients with mitral or aortic stenosis can be benefited now by cardiac surgery During operation on the heart itself the above considerations apply with even greater force

PERICARDIAL CAUSES

Large pericardial effusions of sudden onset often cause severe compression of the heart and a decrease in the venous return resulting in a diminution of cardiac output The effusion may be hemorrhagic due to trauma or serous due to infections usually rheumatic fever or more rarely tuberculosis The symptom complex of cardiac tamponade is pathognomonic and consists of a rapid decline in blood pressure with dyspnea and engorgement of the cervical veins and the liver On percussion the area of cardiac dullness is increased Auscultation reveals decreased heart sounds and often the presence of a pericardial friction rub A roentgenogram shows a diffuse enlargement of the cardiac shadow Electrocardiographically there is a decreased amplitude of the QRS complex (Fig 3)

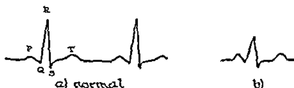


FIGURE 3

Treatment consists of pericardial paracentesis if ligation of a ruptured vessel is required surgical intervention is necessary

CARDIAC ARRHYTHMIAS

Disturbances in cardiac rate and rhythm or cardiac arrhythmias as they are called are frequent manifesta

tion of structural changes in the heart due to disease During operation when factors such as anoxia the toxic effects of anesthetic agents or stimuli arising from the handling of viscera may be active arrhythmias may start as a result of such functional factors in a normal heart In either case whether due to permanent pathologic changes or transient physiologic influences the arrhythmia may lead to hypotension If the cause is not removed quickly or if the proper drugs are not used immediately the lowered blood pressure may lead to dire consequences Most of the arrhythmias that may occur during operation and are serious enough to cause hypotension can be recognized readily and treated It is important therefore that surgeon and anesthetist as well as internist be familiar with them

Classification It is customary to classify the cardiac arrhythmias according to whether the disturbance (in rate or rhythm) is that of impulse initiation or impulse conduction A depression of the normal rhythm initiated at the sinus node may result in sinus bradycardia or sinus arrest which if sufficiently prolonged may cause hypotension and in rare instances sudden death Originally called by Sir Thomas Lewis the vasovagal syndrome the mechanism resulting in fall of blood pressure dizziness and syncope is due to a wide variety of factors including psychic stimuli digitalis certain infectious diseases (influenza virus pneumonia typhoid) carotid sinus pressure and anesthesia The electrocardiogram is characteristic consisting of a prolongation of normal complexes as shown in Figure 4

In operations especially in the region of the neck

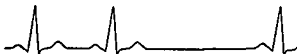


FIGURE 4

that may stimulate the carotid sinus reflex and induce vagal slowing atropine banthine or similarly acting parasympatholytic drugs should be administered pre operatively to paralyze the vagus

Tachycardia Paroxysmal tachycardia of auricular or ventricular origin is a disturbance of impulse ini tiation in which the arrhythmia is initiated in an ectopic focus in either the auricle or the ventricle or more rarely the auriculoventricular node If the tachycardia persists long enough there may result a decrease in cardiac output and a fall in blood pres sure

AURICULAR TACHYCARDIA In paroxysmal auricular tachycardia the auricular and the ventricular rates are regular and constant varying from 150 to 250 per minute The electrocardiographic evidence con sists of absent or abnormal P waves with otherwise normal complexes (Fig 5)

VENTRICULAR TACHYCARDIA Ventricular parox ysmal tachycardia is a less common but more serious



FIGURE 5

form of arrhythmia It may occur under a variety of circumstances Among the drugs that may cause it are even those which are used for the treatment of heart disease such as digitalis quinidine and procaine amide hydrochloride (Pronestyl) Others are Dilantin tetraethylammonium chloride and the central nervous stimulant used in the treatment of barbiturate poisoning nikethamide (caffeine amphetamine coramine mixture)

Potassium intoxication such as may occur following an incompatible transfusion reaction or in acute renal failure may cause arrhythmias Potassium however when its level in the blood has been depressed below normal as a result of overdosage of digitalis is useful as an antiarrhythmic agent for the treatment of the digitalis induced arrhythmias

Anxiety has been shown to cause ventricular tachycardia It has been suggested as a possible explanation for cases of sudden death in individuals with normal hearts

Cardiac catheterization may be a cause of serious arrhythmias Several cases of premature ventricular systoles ventricular tachycardia and fibrillation have been reported following this procedure It is not uncommon in patients with severe myocardial disease especially after myocardial infarction

The occurrence of ventricular arrhythmias during major surgery is apparently on the increase They occur not only in those with diseased but also in those with normal hearts and in the young as well as in the old. Arrhythmias of ventricular origin arise during operations in the thorax on pulmonary and cardiac structures and in the region of the great vessels

with their multiple cardio-inhibitory and accelerator reflex potentials They also occur in operations in other areas and on other systems of the body

No single factor is responsible for the arrhythmia However the combination of factors that conspire to cause ventricular arrhythmias and lead to the dreaded ventricular fibrillation and cardiac arrest may be summarized as follows the patient especially when some degree of heart disease is present the anesthesia—multiple agents depth of anesthesia intubation anoxia the operation—especially cardiac and thoracic surgery Of all the factors anoxia and an accentuated vasovagal *reflex are perhaps the most important*

Diagnosis The diagnosis of ventricular tachycardia is usually difficult without the aid of the electrocardiogram However it should be suspected at the bedside or in the operating room in patients who show failure of vagal stimulation to produce an effect *a jugular pulse rate slower than the ventricular* rate irregularities of length of cycle and changing intensity of the first heart sound The electrocardiogram is as in Figure 6

Treatment Procaine amide (Pronestyl) is a valuable drug for the control of ventricular arrhythmia It may be given orally intramuscularly or intravenously When given intravenously it may cause hypo



FIGURE 6

tension if too large a dose is used the dose should not exceed 100 mg per minute Norepinephrine will counteract the hypotensive effects of Pronestyl over dosage By mouth the usual dose is 250 to 500 mg repeated in 2 hours but much larger doses may be needed In emergency situations it is best to use the intravenous route cautiously and to have norepinephrine handy

Quinidine much older than Pronestyl as an antiarrhythmic drug especially in the treatment of auricular fibrillation is also a valuable agent for the treatment of the ventricular variety It may be administered intravenously with safety if certain precautions are observed The drug in the form of the lactate is diluted in 100 cc of glucose and administered at the rate of 2 cc per minute Frequent ECGs are taken so that the infusion may be stopped at the first evidence of toxicity and so that it may be discontinued immediately after normal rhythm has been restored

Digitalis the oldest of all antiarrhythmic drugs has a more limited field of usefulness in the therapy of this disorder However in the treatment of the emergencies due to auricular fibrillation either acute circulatory collapse or congestive failure certain intravenous preparations are of great value Lanatoside C acetyl strophanthidin and ouabain are the intravenous digitalis preparations most commonly used in emergencies because of their rapidity of action and rapid elimination Ouabain is used at the Royal Victoria Hospital for such cardiac emergencies in a dosage of 0 5 mg followed within an hour by 0 25 mg if needed as an intravenous solution of 100 cc of glucose containing the drug

The routine preoperative use of quinidine or Pronestyl to prevent arrhythmias occurring is inadvisable because of their depressant effect on the myocardium and the consequent increased susceptibility to cardiac arrest Their use should be reserved for the treatment of arrhythmias as they arise when by intravenous or intracardiac injection they act immediately Digitalis may be dangerous if used in the presence of ventricular fibrillation

Ventricular Fibrillation CAUSES One of the most serious of the cardiac arrhythmias is ventricular fibrillation It is an irregularity of increased rate due to the continuous initiation of impulses by an ectopic focus in either ventricle (Fig 7) The causes are coronary arteriosclerosis digitalis intoxication anesthesia especially cyclopropane in excess and other factors leading to anoxia during operation as already mentioned It may be preceded by ventricular tachycardia and if not treated immediately it may terminate fatally in cardiac arrest Therefore the prompt recognition and treatment of hypotension as a manifestation of this form of cardiac arrhythmia is of utmost importance

DIAGNOSIS A sudden and profound fall in blood pressure during an operation always should arouse suspicion of ventricular fibrillation or cardiac arrest



FIGURE 7

However the other causes of acute hypotension—blood loss vagal arrest vascular dilatation—should be considered first It may be that only by an ECG tracing can ventricular fibrillation or standstill be confirmed or ruled out Or it may be that to wait for confirmatory evidence of the ECG is to wait too long There are dangers in both courses of action Opening the chest with its attendant trauma and infection may place an unsupportable burden on an already seriously ill patient On the other hand delay in doing just that may jeopardize his chances for survival

TREATMENT A middle course would seem to be as wise as it is valorous and consists of the following procedure for the treatment of cardiac arrest (1) Remove excess anesthesia by hyperventilation with oxygen (2) Compress the heart from without the thorax i e through the diaphragm (3) Inject 10 cc CaCl 10 per cent or 1 cc. epinephrine 1 1000 into the left ventricle through the chest wall In many cases this will suffice to restore normal rhythm

The treatment of ventricular fibrillation is less satisfactory than that for cardiac arrest It consists of (1) The intracardiac injection of 10 cc procaine 10 per cent to produce standstill and then manual compression to maintain circulation until the heart beats normally (2) Return of normal heart beat is aided by CaCl and epinephrine (3) If the chest has been opened the aorta should be compressed to help maintain cerebral and coronary circulation and also aid in the flow of the intraventricularly injected drugs into the coronary circulation (4) The use of an elec

trical defibrillator may be required if these measures fail

Throughout the period during which resuscitative measures are being applied to the heart artificial respiration must be given also to ensure adequate oxygenation and transfusions continued at a more rapid rate to maintain an adequate venous return to the heart

Heart Block The disturbances of impulse conduction that are important in causing hypotension are sinoauricular block and auriculoventricular block The former is an interference in the transmission of the impulse originating in the sinoauricular node The physiopathology of this arrhythmia is the same as for sinus bradycardia and sinus arrest described previously In sinoauricular block however the interference in impulse transmission is due to structural changes in the heart Not only the manifestations but also the diagnosis and the treatment are those already described for sinus arrest

Auriculoventricular block is an interruption of impulse conduction at the AV node It may be temporary when occurring during infection or anesthesia or permanent due to arteriosclerosis syphilis rheumatic fever or hypertension Complete heart block gives rise to the phenomenon known as the Stokes Adams syndrome This consists of episodes of hypotension syncope and convulsions due to ventricular asystole Although the SA node imitates normal impulses they are blocked at the AV node Since they are not conducted into the ventricles the latter initiates its own rhythm in an ectopic focus either in



FIGURE 8

the junctional tissue or in the left or the right ven tricle At times ventricular asystole takes place (Fig 8)

Cardiac arrest may occur also in heart block due to disease of the auriculoventricular conduction system or to carotid sinus hypersensitivity The treatment of heart block consists of the administration of ephed rine epinephrine and related compounds Atropine may be useful in diminishing vagal sensitivity In the presence of heart block quinidine and Pronestyl are dangerous drugs and should not be used because they may induce fibrillation of the ventricle by de pressing the basic idioventricular pacemaker But as already mentioned in patients with previously normal conductive mechanisms who develop ventricular fibril lation e g during surgical operation quinidine or Pronestyl is the drug of choice

In complete block the rate usually averages about 40 per minute and the rhythm is regular Electro cardiographically the P waves have no uniform time relationship to the QRS complexes which are aber rant The prevention of attacks is aided by ephed rine During an attack norepinephrine is used intra venously

Myocardial Infarction The term medical shock has been used frequently to describe the clinical fea tures of severe myocardial infarction Present are all

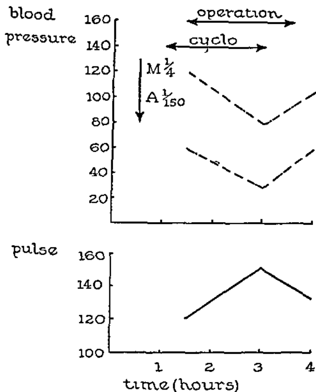


FIG 9A The deleterious effects of preoperative medication with atropine in a case of mitral stenosis with hemolytic anemia in which a splenectomy was performed Atropine prevented the vagus from counteracting the effects on the heart rate of the sympathetic stimuli induced by the operation Tachycardia ensued with engorgement of the lesser circulation which was followed by inadequate filling of the left ventricle and hypotension



FIGURE 8

the junctional tissue or in the left or the right ventricle At times ventricular asystole takes place (Fig 8)

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In complete block the rate usually averages about 40 per minute and the rhythm is regular Electrocardiographically the P waves have no uniform time relationship to the QRS complexes which are aberrant The prevention of attacks is aided by ephedrine During an attack norepinephrine is used intravenously

Myocardial Infarction The term medical shock has been used frequently to describe the clinical features of severe myocardial infarction Present are all

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TREATMENT Therapy consists of oxygen rapid acting digitalis preparations and norepinephrine The operation devised by Trendelenberg for treatment of pulmonary embolus has had very little success Persistence in the use of symptomatic treatment especially vasoconstrictors may be rewarding

Cardiopulmonary Causes Patients with pulmonary hypertensive disease may have episodes of hypotension during exercise or excitement At such times the increase in pulmonary arterial pressure stimulates a vagal reflex resulting in slowing of the heart and arteriolar dilatation with a fall in systemic arterial pressure

Other pulmonary causes of cardiocirculatory failure are acute cor pulmonale such as that due to tension pneumothorax or mediastinal shift due to hemorrhage etc pleural shock from therapeutic pneumothorax or thoracentesis and hyperventilation

CONCLUSION

The management of shock because of its emergency nature has been compared with the therapy of diabetic coma in that it is not enough to start treatment write orders and return later to see how the patient is progressing Some instances of cardiocirculatory failure present the most serious of all emergencies Probably no other conditions demand such resourcefulness close supervision and sense of urgency during the entire period of treatment The effects of anoxia are so serious that in severe shock the period during which transfusions and other resuscitative measures may be effective is often measured only in minutes occasionally even in seconds but almost never in hours

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